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(54) IMPROVEMENTS RELATING TO REACTION VESSELS

(71) I, PAUL ROLF STEHNING, a German national, of Thüringer Strasse 2, 6391 Grävenwiesbach in Taunus, Hessen, Germany, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to reaction vessels, especially those used for the treatment of highly viscous masses.

The invention is an improvement in, and a modification of, the invention described and claimed in Specification No. 1,304,257. The invention of Specification No. 1,304,257 is defined in claim 1 of that Specification as a reaction vessel for the treatment of viscous masses which vessel comprises a vertical container of circular cross-section having a base portion of which the lower part is downwardly tapering and substantially frusto-conical in shape and the upper part is in the form of a ring encircling the frusto-conical part, the bottom of the ring having at least one aperture therein, and a stirring mechanism having a plurality of arms, at least one of the arms carrying a scraper which extends into the encircling ring and each arm having attached thereto at least two blades which are radially spaced from each other, the arms and the blades being substantially completely accommodated in the base portion of the reaction vessel and each blade, the top of which is situated just below the normal level of liquid when the reaction vessel is in use, extending to a region close to the frusto-conical part of the base portion of the reaction vessel, and at least one annular separating wall, each of said walls being provided with at least one aperture therein, being connected either to the arms of the stirring mechanism or to the base of the reaction vessel and, when more than one is present being radially spaced from each other. the arrangement of the blades and the wall(s) being such that each wall extends axially between adjacent blades on the same arm and acts to brake viscous material flowing in the radial direction.

The reaction vessel specifically described in the parent specification has the form of a vertical container with a substantially frusto-conical downwardly tapering base; it further comprises a driven stirring mechanism having a vertical shaft and comprising substantially radially extending stirring arms and substantially axially extending stirring blades attached thereto, which are submerged below the level of the highly viscous mass which is continuously introduced into the reaction vessel, the level of the highly viscous mass being automatically adjusted to a predetermined position at the output of the mass by controlling at least the input of the mass to the reaction vessel. Furthermore, the stirring arms and the stirring blades attached thereto are almost entirely accommodated in the production chamber defined in the frusto-conical base of the reaction vessel, and the stirring blades, which start in a vicinity of the level of the viscous mass, extend to a region close to the frusto-conical base of the reaction vessel. The stirring blades have radial intermediate spaces between one another, extending along their entire length, and annular separating walls provided with passage openings and firmly connected to the base pass through said intermediate spaces. The separating walls define ring-shaped chambers or channels concentric with the shaft of the stirring mechanism, and serve as a braking means for the mass radially escaping through the passage openings therein.

Such a reaction vessel is especially suitable for the treatment of polymeric products, such as polyamides and polyesters,

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polycaprolactam, for example Nylon-6, which polymerize under heating and condense in the reaction vessel, with the vapour formed being simultaneously exhausted from the vessel. The stirring blades are especially designed for the treatment of highly viscous masses, the viscosity of which increases by elimination of water in the reaction vessel. The reaction vessel of the parent Application may be used, for example, for the treatment of masses in the range of viscosity between 300 and 5000 poise (at the input of the mass). Solid members are used in the parent Application as stirring blades for masses within the above viscosity range, said blades extending very closely to the lateral walls and the bottom of the ring-shaped channels of the production chamber.

However, my further experiments have shown that the stirring effect in the viscosity range of more than 5000 poise and, for instance, as high as 20,000 poise (at the input of the mass), and particularly the evaporation of such masses as polycondensation products, e.g. Nylon 66, is not satisfactory if solid stirring blades are used, as the danger exists that the stirring blades might push the mass in front of themselves as a more or less closed ring, in particular at the end of the treatment process, without circulating the mass in front of the blade to the extent necesary for the treatment of the mass, said circulation being an important feature of the construction in the parent Application.

The present invention obviates the drawbacks of the reaction vessel according to the parent Application by using stirring blades which have one or more openings extending therethrough. The openings are of such a size that the flow of the mass moving in relation to the rotating stirring blades and along the ring-shaped channels is divided in the region preceding the stirring blades in the direction of their rotation and only partially moves over the stirring arms, whereas the other part continues its movement underneath the arms (that is, through the openings). This feature is new when compared with the embodiment according to the parent Application, where the flow of the mass underneath the stirring arms cannot exist and the whole stream of the mass moving in relation to the stirring arms has to move thereover, while a part of the mass undergoes no such relative movement whatsoever, yet is shifted along the bottom of the ring-shaped channel co-operating with the particular stirring blade.

The present invention provides a reaction vessel for the treatment of viscous masses which vessel comprises a vertical container of circular cross-section having a base portion of which the lower part is downwardly tapering and substantially frusto-conical in shape and the upper part is in the form of a ring encircling the frusto-conical part, the bottom of the ring having at least one aperture therein, and a stirring mechanism having a plurality of arms, at least one of the arms carrying a scraper which extends into the encircling ring and each arm having attached thereto at least two blades which are radially spaced from each other, the arms and the blades being substantially completely accommodated in the base portion of the reaction vessel, the vessel also comprising at least one annular separating wall attached to the base of the reaction vessel, each of said walls having at least one aperture therein antd the walls, when more than one is present, being radially spaced from each other, the arrangement of the blades and the wall(s) being such that each wall extends axially between adjacent blades on the same arm and acts to brake viscous material flowing in the radial direction, each blade extending close to the annular separating wall(s) and the frusto-conical part of the base portion of the vessel and each blade having one or more openings extending therethrough.

The invention also provides a method of treating a viscous mass which comprises stirring the mass in a reaction vessel in accordance with the invention, the size of each blade opening being such that a partial stream of the viscous mass passes through the opening, while the blade forces another partial stream to flow over the stirring arm.

By a suitable selection of the cross-section of the openings of the stirring blades in accordance with the degree of viscosity of the mass to be treated, the above-mentioned phenomenon of division of the flow can be adjusted in such a manner that a circulating flow results in the mass, caused by jamming of the mass in front of the stirring blades and in front of the advancing edge of the stirring arm, said flow proceeding from the advancing front edge of the stirring arm against the direction of rotation of the stirring mechanism, then toward the bottom of the ring-shaped channel, and finally back to the front edge of the stirring arm. A partial stream in the form of a boundary layer splits from the mass behind said front edge and proceeds over the stirring arm, said partial stream itself beginning in the vicinity of the front edge by the circulat-

The first-mentioned division of the rela-

ing or turbulent flow.

tive flow in partial streams above and below the stirirng arm is very advantageous in itself, as well as in connection with the above-mentioned circular flow, because a substantially higher movement of the surface of the mass is caused in front, above and behind the stirring arm, and both this, and

the circular flow, are very dseirable for purposes of evaporation under vacuum and/or heat exchange with the heated base of the reaction vessel. However, it is not essential that the above-mentioned circulation and/or division of the flow be created at or in front of the advancing edge of the stirring arm; it is also possible to provide a stirring arm with one or more passage openings immediately at, or slightly in front of, the corresponding stirring blade, and let the upper partial stream start at this passage point above the stirring arm and flow thereover.

The main advantage of the invention is that masses with high viscosity of more than 5000 poise (and up to a magnitude of 20,000 poise) can be satisfactorily treated, in particular evaporated in a comparatively short time, a favorable, uniform spectrum of duration of the residence of the mass in the reaction vessel being obtained. Regardless of these special advantages for treatment of highly viscous masses with an exceptionally high viscosity, the reaction vessel may be used for the treatment of masses with lower viscosity of less than 5000 poise with similar advantages, for instance, for shortening the treatment time of the mass or for improvement of the spectrum of the duration of the residence of the mass in the reaction vessel. Furthermore, experiments have shown that the improved reaction vessel is suitable not only for the evaporation of synthetic resinous masses, such as condensation products or polymerization products, but it also can be used to advantage as a heat exchanger for other viscous masses, for instance, syrups, tar products, asphalts with or without chemical reaction, i.e. for physical treatment during cooling and/or heating. In the case of cooling, a cooling medium instead of a heating medium is circulated through the jacket of the reaction vessel.

A further advantageous field of use of the reaction vessel is as a mixer for several highly viscous masses introduced in the reaction vessel and/or admixture of coloring agents, pigments, stabilization agents or other materials.

In all fields of use of the invention, the mass is introduced into (or discharged from) the reaction vessel during its operation through a central opening in the lower part of the base of the reaction vessel, for instance, by means of a pump and/or a screw conveyor; it is conducted radially outwardly (or inwardly) through the passage openings in the dividing walls of the production chamber and discharged from (or introduced into) the reaction vessel at the upper edge of the production chamber by means of conveyors, e.g., one or more screw conveyors which mav adjoin an outer base ring in which a scraper is provided, in accordance with the description in the parent Application.

As in the parent Application, the angle of taper of the base of the reaction vessel can be chosen in accordance with the degree of viscosity of the mass to be treated in a magnitude increasing with the viscosity of the mass. Thus an acute angle is selected for instance, for a viscosity of 300 poise and an obtuse angle selected for higher viscosities. The choice of the angle also depends on the desired duration of the residence of the mass in the reaction vessel, depending on the properties of the mass and its proposed treatment.

Further examples of suitable masses for use in the reaction vessel of the invention are syrups, sugar masses, milk for the production of desiccated milk powder, non-condensing or non-polymerising synthetic resins, foodstuffs and food elements, which should be pre-dried in the reaction vessel. The reaction vessel and the process of the invention can also be used for the treatment of cellulose masses, for instance, for extraction of water in the manufacture of paper; extraction can then be completed, for instance, in a paper machine to a lesser extent.

The operation of the reaction vessel can also be conducted in such a manner that the mass is introduced to the outer edge of the production chamber, then proceeding in the radial direction through the passage openings in the dividing walls toward the center of the reaction vessel and discharged from there by means of a conveyor, for instance, a screw conveyor.

In accordance with the method of the invention, it is very important that the cross-section of the openings in the stirring blades correspond to the viscosity of the treated mass. In general, the cross-section of the openings is chosen in this sense for a certain range of viscosity, for instance, on one hand up to 5000 poise, and on the other hand for more than 5000 poise, and the cross-sectional area of the opening in each of the stirring blades is chosen to be greater the higher the viscosity of the mass to be treated.

The cross-section of the openings in the stirring blades may be adjustable so that there is no need to have several different types of reaction vessels in stock in order to respond to particular needs of the purchaser, and only portions of the reaction vessel need to be replaced.

In one method of adjusting the cross-section of the openings, the parts of the stirring mechanism which determine the cross-section of the openings in the stirring blades, may be replaced by corresponding parts having openings of different

cross-section so that the cross-section of the openings is larger, the higher the viscosity of the mass to be treated. For example, the openings in the stirring blades, and also the openings in the dividing walls of the stirring channels, can be adjusted by replacement of one set of stirring arms by another set in accordance with the need. Alternatively, the entire portion of the stirring mechanism in the production chamber may be replaced by another portion of the stirring mechanism, in which the openings in the stirring blades have larger cross-section, the higher the viscosity of the mass to be treated, and wherein the form of the stirring blades is adapted to the conicity, i.e. the angle of taper corresponding to the angle of the base of the reaction vessel which angle may be made dependent on the respective desired duration of residence of the mass in the reaction vessel. However, in general, the possibility of exchange of the whole stirring mechanism or of a member thereof is applicable only in a certain range of viscosities in view of the above, as the angle of the base must remain the same.

The cross-section of the passage openings in the stirring blades should normally amount to 20% to 40% of the surface of each stirring blade for viscosities up to 5000 poise, whereas it can amount to more than one half of the active surface of the stirring blades for higher viscosities.

The reaction vessel according to the invention is also suitable for multi-stage continuous evaporation of masses of which the viscosity is continuously increased in the course of this process. Consequently, a reaction vessel according to the invention may be used for all stages of the treatment of the mass. In such a case only the angles of taper of the bases of the reaction vessels and the cross-sections of the openings in the stirring blades are chosen in such a manner as to increase from one stage to another.

While simple stirring arms are used in the reaction vessel according to the parent Application, said arms are constructed so as to correspond to the demands of strength, and hence comparatively narrow, radially tapering stirring arms are used. The division of the flow of the mass which is made possible by the present invention assisted by the fact that the stirring arms serve as guiding surfaces for the partial stream of mass proceeding over them, and thus at least the upper part of the stirring arms is advantageously constructed so as to have a lift surface in the form of a profile of airplane wing shape. Thus the stirring arms advancement of the flow on the upper side. are in their direction of rotation comparatively wide.

For similar reasons, and those of at least the upper surface of the trailing end of the stirring arms is advantageously tapered towards the bottom of the corresponding ring-shaped channel, preferably in such a manner that the profile of the upper and lower surfaces of the stirring arms merges with the adjoining stirring blades. Thereby undesirable dead zones of the flow in front of, and behind the stirring blade, are avoided.

The speed of the stirring blades also depends on the viscosity of the mass to be treated and on the kind of treatment process. The speed is adjustable. For mixing, heating and cooling of masses having a viscosity in the range of 1000 poise to 5000 poise, the speed is advantageously approximately ten revolutions per minute. For evaporation, for instance, of polyesters in a viscosity range of up to 3000 poise, a speed of not more than four revolutions per minute has proved to be advantageous, because otherwise the expenditure of power is unnecesarily high, without improving the efficiency. For any masses with a viscosity of up to 3000 poise, a speed of four revolutions per minute or less is advantageously used, as this results in gentle treatment of the product.

As the tangential rotational speed of the stirring blades is greater in the larger, radially outwardly positioned ring-shaped channels than in the inner ring-shaped channels in proportion to the radius, the magnitude of the cross-sectional openings is advantageously chosen differently from one stirring blade to another and from one ring-shaped channel to another, in such a manner that the size of the openings in the stirring blades relative to the total surface area of the blades increases from the radially innermost to the radially outermost stirring blades. In order to obtain this change in the size of the openings, each blade may have a vertical tongue formed by the opening therein, the tongue s progressively changing in length in the radial direction of the stirring mechanism.

According to a preferred embodiment of the invention, the stirring arm is constructed at its advancing edge as a forwardly directed cutting edge which assists in the division of the flow of the mass in two partial streams, and furthermore, the stirring arms are preferably provided with guiding surfaces, which protrude in front of the advancing front edge of the stirring arm and proceed above its upper surface and upwardly and along this upper surface towards the rear, and cooperate with the dividing walls of the ring-shaped channels, serving the purpose of guiding the circulating flow originating at the dividing point and concerning the upper stream.

The invention will now be described, by

way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a vertical section through a reaction vessel for the treatment of composition of high viscosity;

Fig. 2 is a vertical section on enlarged scale and in greater detail through a stirring mechanism for the reaction vessel shown in Fig. 1;

Fig. 3 is an elevational view of the stirring mechanism of Fig. 1;

Fig. 4 is a top plan view of the stirring mechanism of Fig. 3;

Fig. 5 is a schematic sectional view taken along line A-B of Fig. 3 in the direction of the circumference, of a stirring blade in connection with a guiding surface showing the flow above and below the stirring blade;

Fig. 6 is a view similar to Fig. 1 of another embodiment of the present invention;

Fig. 7 is an elevational view of the stirring mechanism of the embodiment according to Fig. 6;

Fig. 8 is a top plan view of the stirring mechanism of Fig. 7; and

Fig. 9 is a schematic sectional view taken along line A′-B′ of Fig. 6 through the stirring blade similar to Fig. 5.

Referring to the drawing, the reaction vessel consists of two main parts, a lower part 1, comprising a production chamber and a sump for liquid, and an upper part 2, incorporating a vapor chamber. Both parts of the reaction vessel have a double wall 3 for the circulation of a heating fluid (generally steam), and inlet and outlet ports which are not shown. The parts of the reaction vessel are interconnected by means of flanges 4 to provide a liquid-tight and vacuum-tight seal.

The upper part of the reaction vessel has a vapor outlet port 5, to which is connected a vacuum source (not illustrated) for drawing off the vapor from the composition to be treated in the reaction vessel during evaporation.

In the illustrated embodiments, the angle of the taper of the base of the reaction vessel is designed to be used for treatment of masses with a starting viscosity of more than 300 poise. For viscosities of up to 20,000 poise a more and more obtuse angle of the base of the reaction vessel is preferable. The embodiment of Figs. 6-9 herein is intended for viscosities of the mass less than 5000 poise but in accordance with the intended use, for example as a mixer or heat exchanger or for other physical or chemical uses, the base of the reaction vessel may have an acute or a more obtuse angle.

The composition to be treated is fed by means of a pump 8; powered by a motor 7, through an inlet port 9 into a charging pipe 10, the upper end of which terminates at the center of the base of the reaction vessel. The lower end of the pipe 10 is closed by means of a vacuum gland 11 and constitutes the bearing for a drive shaft 13, powered by a motor 12, which shaft drives the stirring mechanism 14, which is accommodated in the producion chamber 15. Between the lower end 16 of the hub 17 of the stirring mechanism and the gland 11, the drive shaft 13 in the pipe 10 can take the forms of a conveyor screw 18 for continuously passing the composition into the reaction vessel, when the composition is of high viscosity and the delivery capacity of the pump 8 is not adequate. The moving material passes through a central hole in the base 6 and an open annular passage 19 in the hollow hub, 17, and enters the stirring mechanism 149 through openings 22 at the lower end of the hub 17.

The stirring mechanism comprises a plurality of arms 20, for example three arms (see Figs. 3 and 4), which extend radially outwards from the conical hub 17, and blades 21 which are secured to the undersides of the arms. For simplicity, the stirring arms 20 are not shown in Fig. 1. The hollow hub 17 contains outlet orifices 23 for the composition fed to it. The flow of the composition is set and automatically regulated, according to its viscosity, by means of a restrictor or any other known setting and regulating device (not illustrated) in the feed pipe 8*a* between the pump 8 and the port 9, and by controlling the rate of speed of the drive 7, so that the level 24 of the liquid is set, as shown by a broken line in Fig. 1, at a small distance, e.g. a few millimeters, above the upper sides of the arms 20 of the stirring mechanism.

The blades 21 extend from the arms of the mechanism to a point close to the upper side of the base 6 of the reaction vessel and taper radially to match the angle of taper of said base. The blades are radially spaced from each other. Into these spaces there project annular separating walls 27 which are rigidly connected to the base 6 and contain openings 28 near the base. These separating walls serve the purpose of braking the centrifugal action produced by the stirring mechanism 14 on the composition, insofar that they force the composition to flow through the narrow openings 28. An outermost wall 27 serves as an overflow for discharge of the composition. The separating walls 27 form, moreover, closed ring-shaped, concentric channels 55, the bottom of which is formed by the base 6 of the reaction vessel.

Figs. 1 and 3 to 5 show a first embodiment of the stirring blades 21, in which openings 43 are provided having the form

of cutouts in the stirring blades, which openings extend over more than the half of the surface, i.e. approximately 70% to 80% of the surface of each stirring blade.

Openings of such a magnitude are provided preferably for treatment of a mass with a higher viscosity, in particular with viscosity of more than 5000 poise. A central tongue 61 and a circumferential part 62 of each stirring blade are formed by these cutouts 43. The circumferential part 62 adjoins the base 6 and the separating walls 27 and forms the upper part of the stirring arms 20. In the stirring blades adjoining the hub 17, the middle tongue 61 is omitted. In general, the absolute magnitude of the openings 43 increases in the radial direction from outside to inside to such an extent, as the depth of the production chamber 15 increases from outside to inside in accordance with the angle of taper of the base 6 of the reaction vessel. This increase in the magnitude of the openings 43 in the stirring blades is desirable, as the circumferential speed of the stirring blades increases in proportion to the distance of the particular stirring blade from the central axis of the stirring mechanism 14, and the mass passing through the openings in a given time must be the same in all channels (except when the stirring mechanism is first started).

The stirring blades 21 are omitted from the right-hand side of Fig. 1, and the stirring arms 20 are omitted from both sides of Fig. 1, in order to make clear the construction of the ring-shaped channels 55.

Figs. 3, 4, 5, 7 and 9 show a guiding surface 64 above a operating wall 27 and at the upper part 59 (see Fig. 5) of each stirring arm 20, said guiding surface having the approximate profile of an airplane wing and protruding considerably in front of the front 56 of the stirring arm and also slightly behind the end of the trailing end 57 of the stirring arm. According to Fig. 5, the stirring blade 21 of this embodiment of the invention is attached in a rear region of the lower side of the stirring arm, wherein the advancing end 56 projects in front of the stirring blade and the rear end 57 turns towards the rear side of the stirring blade by a curved portion.

Near its upper edge, the base of the reaction vessel is formed as an encircling outer base ring 30, which constitutes the outermost part 31 of the production chamber. The ring 30 has a substantially horizontal bottom portion 30*a* and a vertical wall portion 30*b*, which defines the production chamber and merges with the flange 4 of the lower part of the reaction vessel by means of angled portions.

In the annular bottom part 30*a* there is at least one discharge orifice 32 for the product. The sides of the outer ends of the arms 20 of the stirring mechanism carry scrapers 33 which occupy most of the outer-part 31 and sweep over the parts 30*a* and 30*b* of the base ring 30. As particularly shown in Figs. 3 and 7, the parts of the scrapers 33 rotating in the part 31 slope downwardly from the arms at an acute angle and rearwardly with respect to the direction of rotation 67 in order to improve the action of these scrapers in moving the material that is to be discharged.

Adjoining the discharge orifice 32 is a discharge pipe 34 in which rotates a discharge screw 35 which likewise directly adjoins the orifice 32. The discharge screw 35 and the discharge pipe 34 pass through a connecting portion 29 which, at a wall 39, provides a fluid-tight seal between the double wall of the reaction vessel and the pipe 34, said screw 35 and pipe 34 further extending through a heating jacket 26 which is joined to the connecting part 29 by means of a flange 29*a*. The inlet and outlet ports of the heating jacket 26 for the hot liquid or vapor are omitted from the drawing. The screw is driven by a motor 37, the housing of which is connected to the heating jacket which is closed at its upper and lower ends.

The product discharged by the discharge screw passes through the heating jacket 36 and an outlet port 38, and is thence passed to a storage chamber or for further treatment, e.g. in a further reaction vessel of like construction.

If more than one discharge opening 32 is provided in the base ring 30, then a discharge screw 35, comprising the corresponding component 34, 29, 29*a* and 36 to 39, is fitted in each of these openings.

As can be seen, the stirring mechanism 14 imparts to the composition in the production chamber 15 a centrifugal acceleration whereby, during evaporation, the composition is passed from the central zone of the production chamber through the orifices 28 and, by way of the arms 20 of the stirring mechanism and the outer wall 27 into the outer part 31 of the production chamber. Here, the product that has been subjected to evaporation treatment, is seized by the scrapers 33 and continuously passed to the discharge screw or screws 35. These prevent deposits of the product from forming on the parts 30*a* and 30*b* of the base ring 30, and such deposits are also prevented in the frusto-conical part of the base 6 and on the separating walls 27 by the centrifugal flow of the composition and by the stirring action of the blades 21 and arms 20, upon which no material is deposited either.

During this process, the level 24 of the liquid is automatically held at the short

distance of a few millimeters above the arms of the stirring mechanism by means of a sensing device which may be of the optical or electrical type.

The evaporation and the action of the arms 20 of the stirring mechanism produce bubbles which break up the surface 24 of the liquid, and splashes of the composition can occur above the scrapers 33 which could be deposited in an undesirable manner on the interior wall of the reaction vessel. To prevent this, an anti-splash ring 42 is fitted on the upper edge of the base of the reaction vessel and on the angle part of the base ring 30. The ring 42 projects above the level of the liquid and the base ring. Furthermore, the scrapers 33 each includes a part 33*a* which projects above the arms of the stirring mechanism towards the anti-splash ring 42 and engage the inside of the anti-splash ring, thus serving as a stripping means while also preventing the composition from being deposited on this ring.

Despite the constructional differences of the stirring blades 21 and the stirring arms 20 from those of the parent Application, the operation of the reaction vessel is, in general, the same as in the parent patent. The important feature of the present invention, however, is to be seen in the particular construction and operation of the stirring arms and stirring blades as seen in Figs. 1 and 3 to 5, and particularly Fig. 5.

According to Fig. 5, the cross-sectional profile of the stirring arm is similar to the profile of an airplane wing and the upper surface 59 of the stirring arms carries a guiding surface 64 for the partial stream 65 which flows over the stirring arm. The division of the flow of the composition 68 in the ring-shaped channel 55 into partial stream 65 and 66 is promoted by a front cutting edge 63 of the stirring arm in the course of the relative flow of the composition in opposite direction to the direction of rotation of the stirring mechanism. This division of the flow is caused by the fact that the stirring blade has a jamming effect on the composition acting against the direction of flow 68, which effect increases for smaller cross-sectional areas of the openings 43. This jamming effect produces a reversed circulation flow under the stirring arm in the direction of the arrow 69 and thereby a raising of the composition above the level 24 that the composition would have if the stirring mechanism was stationary so as to be slightly above the upper surface of the guiding surfaces, as shown in broken arrowed lines 70. From this circulating stream, which is also partially reversed, the upper partial stream 65 splits in the form of a boundary layer as characterized by the lines (of crosses) 73, and proceeds over the middle part and the rear end 57 of the stirring arm.

Numeral 73 shows how this upper partial stream splits from the stirring arm and unites in the ring-shaped channel 55 with the lower partial stream which is shown in dash-dotted lines at 72.

This lower partial stream constitutes a part 66 of the total flow 68 which passes through the openings 43.

As soon as stationary flow conditions are produced in the reaction vessel after the charging of the composition into the reaction vessel, and the upper partial stream 65 comes into existence, the sum of the partial streams 72 and 73 behind the stirring blade per unit of time is of course, equal to the total flow of the mass 68 in relation to the stirring arm. Despite this, a part of this total flow is retained in the circulating flows 69 and 71 shown in dotted lines below levels 24 and 70 and thereby new particles of the composition come repeatedly to the surface of the flow, before they escape either in the direction 65 over the stirring arm or in the direction 72 below the stirring arm through the stirring blade, which process greatly promotes the evaporation and other treatment processes, such as mixing or heat exchange. Thereby, the time of duration of residence in the reaction vessel may be chosen shorter, or the throughput of the mass per time unit can be chosen higher and in spite of this still an advantageous result is obtained.

This effect is further promoted in known manner by the fact that as a result of a high vacuum, of, for instance, 0.3 Torr, bubbles are created at the upper surface of the composition, by which the active surface is further increased. It is advantageous that the stirring blade 21 have a curved profile which is a continuation of the profile of the stirring arms, by which the dead spaces in the flow in front and in rear of the stirring arm are eliminated.

In order to obtain the above described production of the circulating streams and the desired relation of these streams i.e. the proportion of the time unit quantity of composition flowing over the stirring arms on the one hand to the quantity of composition flowing through the openings 43 on the other hand, the cross-section of the openings in the stirring blades must be chosen so as to correspond to the viscosity of the composition to be treated. If this cross-section is too small, the jamming at 69 in front of the stirring blades becomes too large and a partial stream will no longer pass below the level 24 through the stirring blades and reach the point 72, but, in practice, the total composition goes over the stirring arm, which is very disadvanageous, because the region of the circulating flow 70, as seen in the direction of movement,

is too short and too high and less mass particles arrive at the upper surface per unit of time.

On the contrary, it is desirable that the larger part or at least half of the flow passes through the openings 43 and remains in the ring-shaped channel.

This objective is achieved in the embodiment of the invention according to Fig. 5 in an advantageous manner, wherein the embodiment is adapted for evaporation treatment of highly viscous masses with a viscosity of, for instance, more than 5000 poise and up to 20,000 poise and more. In Fig. 5 the openings 43 occupy at least 50% and up to 80% of the cross-sectional surface of the stirring blade.

However, if masses with a lower viscosity, of, for instance, below 5000 poise is to be treated, the stirring blades and the stirring arms are adjusted to these relatively low viscosities of the mass and the embodiment according to Figs. 6-9 is used. This embodiment corresponds to Figs. 1-5 as far as the general construction is concerned, and the corresponding parts in Figs. 6-9 are described by the same numerals as in Figs. 1-5.

Structure which is changed is described by the same reference numerals with the suffix "*a*".

Consequently, the stirring arms in Figs. 6-9 are characterized by 20*a*, the stirring blades by 21*a*, the passage openings by 43*a* and the guiding surfaces projecting from the hub 17 by 17'*a*.

The stirring arms 20*a* are, in general, constructed in the same manner as those according to Figs. 3 and 4, as can be seen in Figs. 7 and 8; however, the stirring blades 21*a*, as shown in Fig. 9, are attached to the lower side of the stirring arms 20*a* in such a manner that they extend over almost the entire depth of the ring-shaped channel 55 and far behind the end 57 of each blade, the upper end of the rear face of each blade 21*a* constituting a continuation of the tapered end 57 and the rear face as a whole being curved and turning in an almost vertical direction toward the bottom 6 of the ring-shaped channel 55.

Although the attachment and shape of the stirring blades 21*a* is advantageous for masses with a low viscosity, such blades could also be used in the embodiment according to Figs. 3 and 5.

It is very important for treatment of masses with a low viscosity, for instance, below 5000 poise that only one opening 43*a* be provided in the stirring blade accord- to the embodiment as shown in Figs. 6, 7 and 9 and its cross-section is smaller than the sum of the cross-sections of the openings 43 in each stirring blade in the embodiment of Figs. 1-5. Preferably the opening 43*a* makes up only approximately one-third of the depth of the blade to the bottom 6 of the ring-shaped channel.

Despite this, a flow results with relation of the partial stream 73 flowing over the stirring arms 20*a* to the partial stream 72 flowing through the opening 43*a* of the stirring blade per time unit of about the same magnitude as that shown in Fig. 5 i.e. wherein the larger partial stream passes through the openings 43*a* and the smaller goes over the stirring arm 20*a*; this is a result of the fact that the opening 43*a* gives the mass the same resistance despite its smaller cross-section when a mass with lower viscosity is used, as compared to the larger cross-section of the cutouts 43 relative to the more viscous mass in the embodiment of Figs. 1-5.

Consequently, the circulating stream in the region of the reversed whirl shown in the lower partial stream 66*a* and 69*a*, i.e. the whirl reversed in relation to the oncoming flow 68, is similar to that shown at 69 of Fig. 5; however, the creation of this whirl begins correspondingly also at the lower side of each blade 21*a*, and more particularly at its curved profile with small whirls in the vicinity of the opening 43*a*, which whirls grow as they continue their movement along said lower side, to reach their largest extent at the front edge 63 of the stirring arm. They then change into whirls 71 and 70 with a similar characteristic as in Fig. 5. The whirls 70 continue in the direction of flow 68 over the front end of the stirring arm 20*a* with a smaller diameter, and create, moreover, a boundary layer flow 65, which changes at the rear end of the stirring arm and the stirring blades into the flow 73.

The desired division process according to the invention, as far as the flow conditions in front of the front edge 63 of the stirring arm are concerned, and the desired circulation of the mass needed for the proper treatment of the mass is also obtained for masses with a lower viscosity in the same manner as was described and shown in Fig. 5 for treatment of masses with a higher viscosity.

The invention thus affords the possibility of adjusting the effect of treatment to the viscosity of the starting material by a suitable construction and arrangement of the stirring blades. It is sufficient for this purpose to remove the stirring mechanism 14 as a unit from its shaft, for example, according to the embodiment shown in Figs. 3 and 4, and substitute it by a stirring mechanism provided with other stirring blades, for instance that of Figs. 7 and 8. For this purpose, the upper part 2 of the reaction vessel must be detached from the lower part 1 at the flanges 4.

If the flanges 4 are not screwed together

but welded for reasons of tightness, or both screwed and welded together, the welding seam would have to be broken for this exchange and after the exchange the weld must be restored. A reaction vessel, however, is usually intended to be used for the same mass and the same treatment thereof, so that the substitution of the stirring mechanism can be made in the factory in accordance with the demand, before the parts 1 and 2 of the reaction vessel are welded together. Alternatively, the stirring blades may be detachably attached to the arms in such a manner as to be capable of being substituted by other blades. This possibility of interchangeable attachment of the stirring blades is not shown in the drawings, but is obvious to one skilled in the art.

Fig. 2 shows schematically how the cross-section of the passage openings 43′ of the stirring blades 21 may be changed in accordance with the viscosity of the mass. Although the passage openings of the stirring blades 21 are shown in Fig. 2 as a plurality of circular holes at 43′ for simplifying the drawing the openings could have the form of cutouts 43 or holes 43*a*. The adjustment of the passage cross-section is achieved by means of covering plates 44, which can be optionally attached over one or more of the openings 43′ by means of welding or screws 45 and fastened to the stirring blades 21. Alternatively, a plate 47 (shown in dash-dotted lines) can be attached by screws 48 or welded over one or more openings per stirring blade. In order to be able to change the passage cross-section of the separating walls 27 in accordance with demand, for instance, with the viscosity of the mass or the speed of rotation of the stirring arms, a covering ring 49 can be provided at the elevation of the openings 28 of the separating walls 27 and adjustably attached thereto. According to Fig. 2, the covering ring is provided in the region of the openings 28 with a recess 50, so that the openings 28 can be closed partially or completely.

WHAT I CLAIM IS:—

1. A reaction vessel for the treatment of viscous masses which vessel comprises a vertical container of circular cross-section having a base portion of which the lower part is downwardly tapering and substantially frusto-conical in shape and the upper part is in the form of a ring encircling the frusto-conical part, the bottom of the ring having at least one aperture therein, and a stirring mechanism having a plurality of arms, at least one of the arms carrying a scraper which extends into the encircling ring and each arm having attached thereto at least two blades which are radially spaced from each other, the arms and the blades being substantially completely accommodated in the base portion of the reaction vessel, the vessel also comprising at least one annular separating wall attached to the base of the reaction vessel, each of said walls having at least one aperture therein and the walls, when more than one is present, being radially spaced from each other, the arrangement of the blades and the wall(s) being such that each wall extends axially between adjacent blades on the same arm and acts to brake viscous material flowing in the radial direction, each blade extending close to the annular separating wall(s) and the frusto-conical part of the base portion of the vessel and each blade having one or more openings extending therethrough.

2. A reaction vessel as claimed in claim 1, wherein the opening(s) in each blade occupy a total of from 20 to 80% of the stirring surface of each blade.

3. A reaction vessel as claimed in claim 1 or claim 2, wherein said stirring mechanism includes a replaceable portion to change the size of the opening in the stirring blades.

5. A reaction vessel as claimed in claim 1 or claim 2, wherein the entire rotatable portion of the stirring mechanism in the production chamber is detachable and replaceable by another rotatable portion of the stirring mechanism in which the openings in the stirring blades have a different cross-section.

5. A reaction vessel as claimed in any one of claims 1 to 4, wherein the cross-section of the openings in the stirring blades is sufficiently small to produce a turbulent flow of the mass as a result of jamming of the mass in front of the stirring blades and in front of the advancing front edge of the stirring arms, said flow proceeding first against the direction of rotation of the blades, then towards the frusto-conical bottom wall of the vessel and back to the front edge, where a partial turbulent stream splits behind this edge from the first turbulent stream and flows over the stirring arm and has, behind the edge, the form of a boundary layer.

6. A reaction vessel as claimed in any one of claims 1 to 5, comprising stirring arms the upper surfaces of which have the profile of an airplane-wing.

7. A reaction vessel as claimed in claim 6, wherein each stirring arm has a trailing end at least the upper side of which is tapered toward the bottom of the vessel.

8. A reaction vessel as claimed in claim 7, wherein the trailing end of the stirring arm merges with the stirring blades to define a substantially continuous profile.

9. A reaction vessel as claimed in any one of claims 1 to 8, wherein the openings

are disposed in the lower region of the blades.

10. A reaction vessel as claimed in any one of claims 1 to 9, wherein the opening in each stirring blade is greater in area than one half of the surface area of the stirring blade.

11. A reaction vessel as claimed in any one of claims 1 to 10, comprising a vertical tongue formed in each said blade by the opening therein, the tongues progressively changing in length in the blades in the radial direction of the stirring mechanism.

12. A reaction vessel as claimed in any one of claims 1 to 11, wherein the size of the openings of the stirring blades is different from one annular channel to another.

13. A reaction vessel as claimed in any one of claims 1 to 12, wherein each stirring arm includes an advancing edge portion with a cutting edge which is directed frontwardly and promotes the division of the flow of the mass into at least two streams.

14. A reaction vessel as claimed in any one of claims 1 to 13, comprising guide members on said stirring arms and projecting in front of the advancing front edge of the arm and extending thereabove.

15. A reaction vessel as claimed in claim 14, wherein the guide member has the profile of an airplane-wing.

16. A reaction vessel as claimed in any one of claims 1 to 15, wherein the aperture, or at least one of the apertures, in the ring encircling the frusto-conical part has a discharge worm conveyor directly attached thereto for dischargng the treated mass, and wherein the reaction vessel also comprises a further separating wall which is concentric with the other separating wall(s) and is rigidly attached to the base of the container to serve as an overflow for treated viscous mass which is supplied through a port near the centre of the base of the vessel.

17. A reaction vessel as claimed in any one of claims 1 to 15, which also comprises a discharge port provided with discharge means near the centre of the base of the vessel, the viscous mass being supplied to the ring encircling the frusto-conical part through the aperture or at least one of the apertures, the said aperture(s) being provided with conveyor means for the mass, whereby the mass is radially fed through the reaction vessel to the discharge port.

18. A reaction vessel as claimed in any one of claims 1 to 17, wherein the or each scraper includes a lower trailing portion inclined downwardly at an acute angle.

19. A reaction vessel as claimed in any one of claims 1 to 18, wherein the base of the vessel comprises a double wall jacket for conducting a heat transfer medium at least in its bottom part.

20. A reaction vessel as claimed in any one of claims 1 to 19, wherein the base has an angle of taper not greater than 90° for masses with a viscosity of up to 300 poise and an obtuse angle for masses with higher viscosity.

21. A reaction vessel as claimed in claim 1, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

22. An assembly of a plurality of reaction vessels as claimed in any one of claims 1 to 21, connected in succession for multistage continuous evaporation of masses with increasing viscosity during the treatment.

23. An assembly as claimed in claim 22, wherein the bases of the successive reaction vessels have cone angles which increase from one stage to the next.

24. A method of treating a viscous mass which comprises stirring the mass in a reaction vessel which comprises a vertical container of circular cross-section having a base portion of which the lower part is downwardly tapering and substantially frusto-conical in shape and the upper part is in the form of a ring encircling the frusto-conical part, the bottom of the ring having at least one aperture therein, and a stirring mechanism having a plurality of arms at least one of the arms carrying a scraper which extends into the encircling ring and each arm having attached thereto at least two blades which are radially spaced from each other, the arms and the blades being substantially completely accommodated in the base portion of the reaction vessel and the blades being submerged below the level of the viscous mass, the vessel also comprising at least one annular separating wall attached to the base of the reaction vessel, each of said walls having at least one aperture therein and the walls, when more than one is present, being radially spaced from each other and defining annular channels, the arrangement of the blades and the wall(s) being such that each wall extends axially between adjacent blades on the same arm and acts to brake viscous material flowing in the radial direction, each blade extending close to the annular separating wall(s) and the frusto-conical part of the base portion of the vessel and each blade having one or more openings extending therethrough, the size of each opening being such that a partial stream of the viscous mass passes through the opening, while the blade forces another partial stream to flow over the stirring arm.

25. A method as claimed in claim 24, wherein the viscosity of the mass is 5000 poise or less and the opening(s) in each blade occupy a total of 20 to 40% of the surface area of each blade.

26. A method as claimed in claim 24,

wherein the viscosity of the mass is over 5000 poise and the opening(s) in each blade occupy a total of 50 to 80% of the surface area of each blade.

27. A method as claimed in claim 24, wherein the reaction vessel is as claimed in any one of claims 2 to 21 herein.

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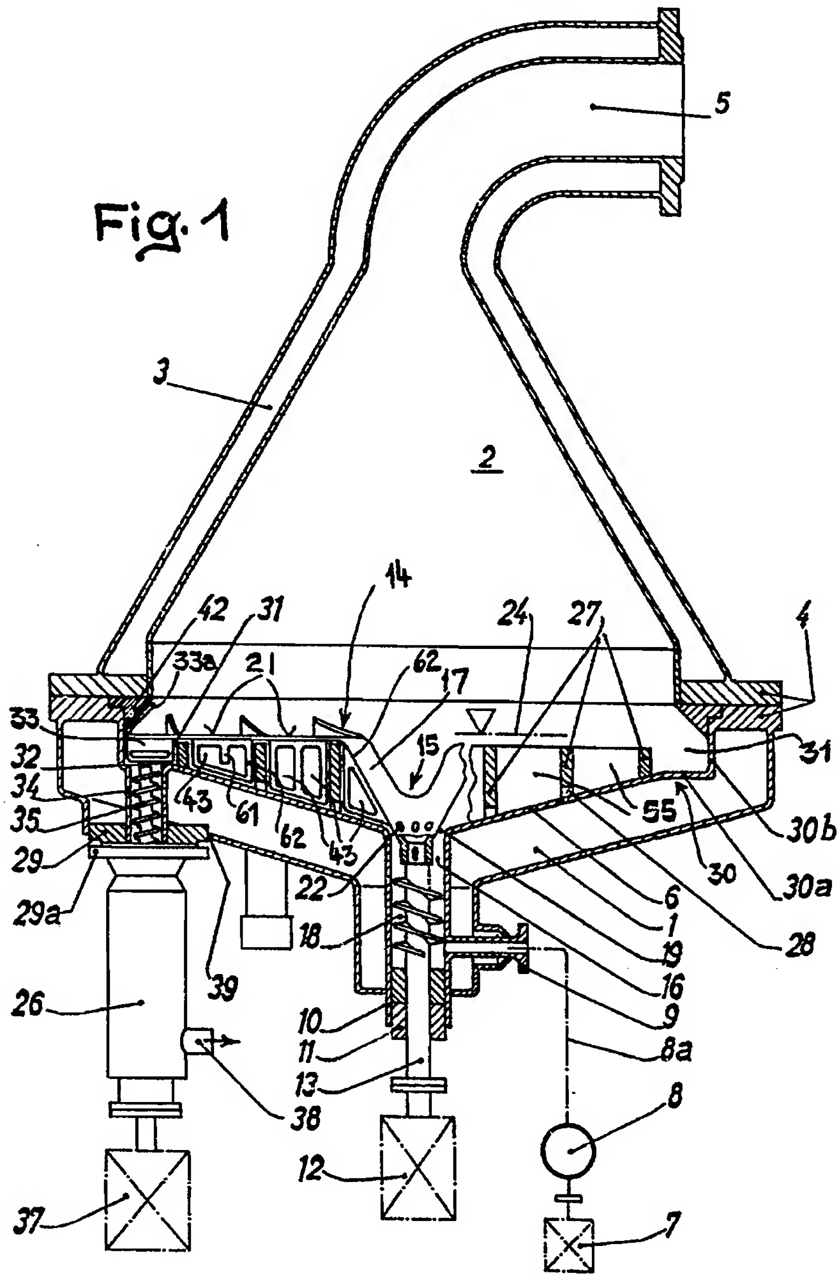
1,325,090 COMPLETE SPECIFICATION
6 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

Fig. 1



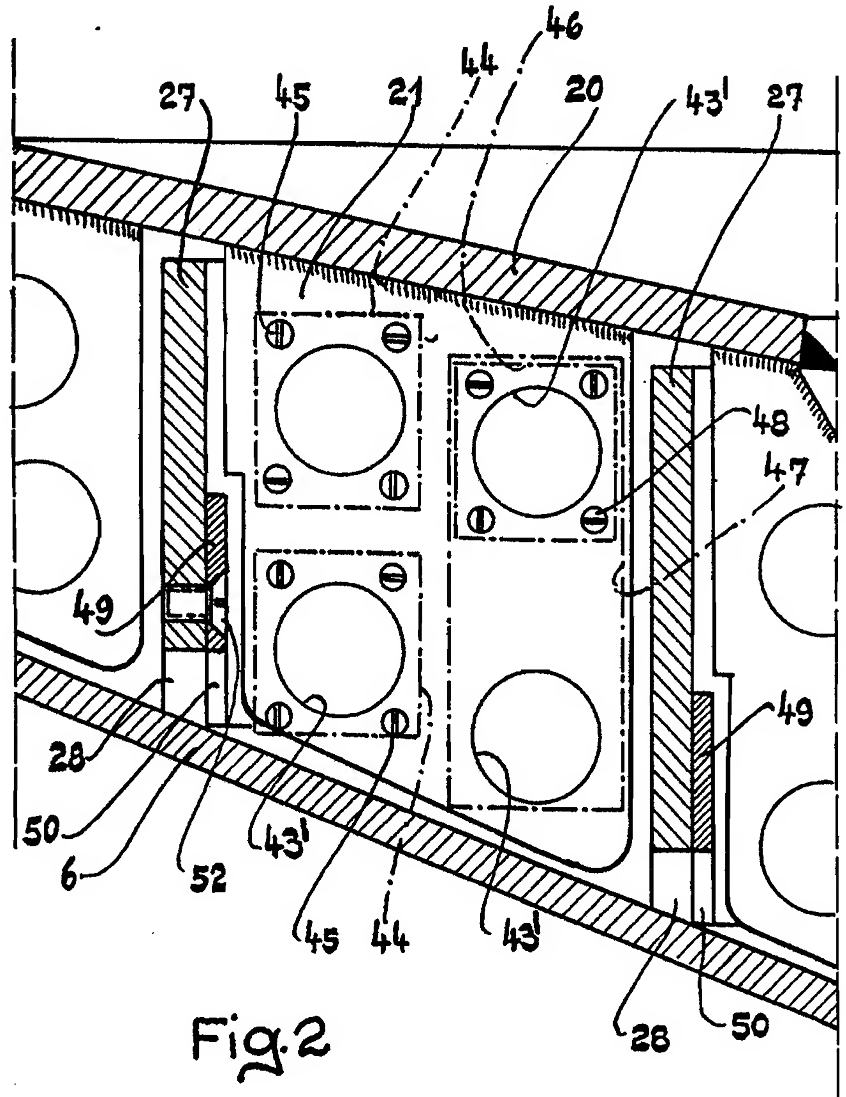
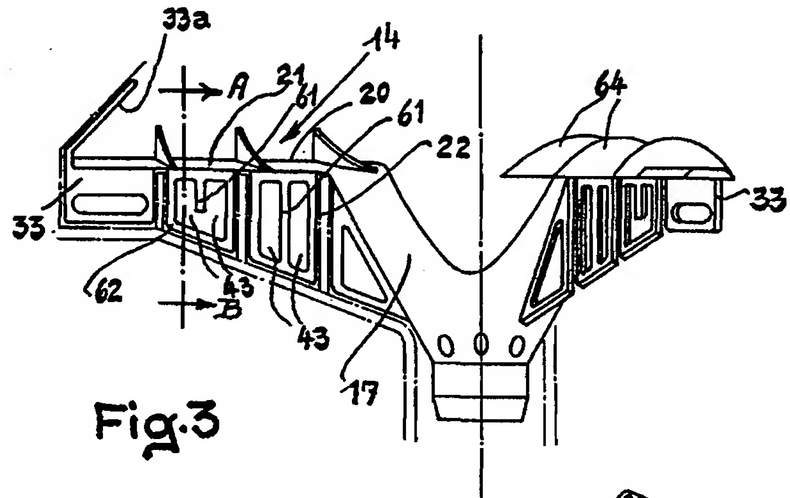


Fig.2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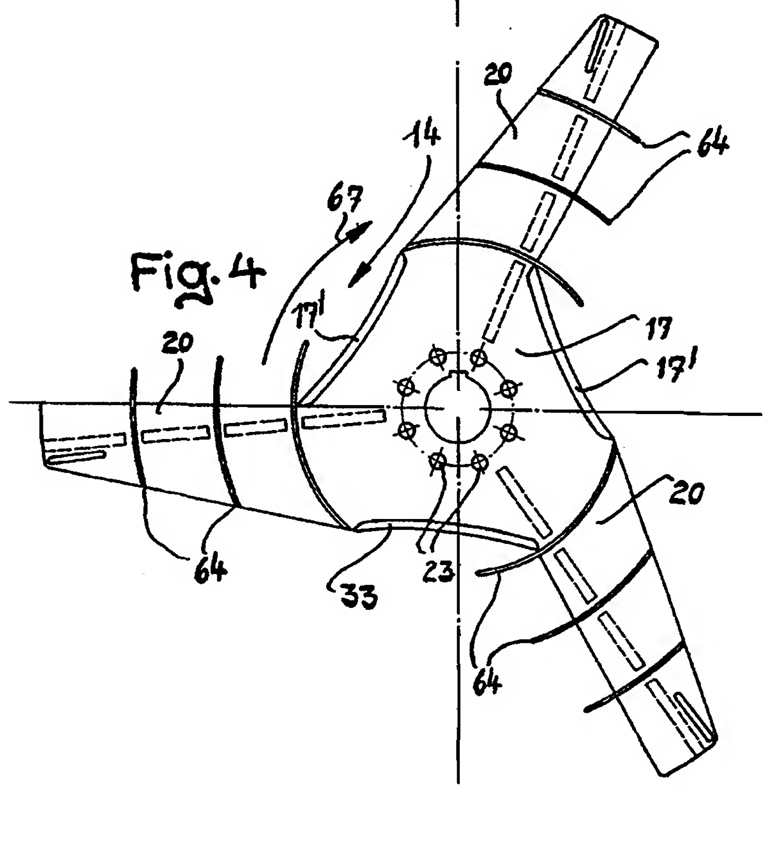
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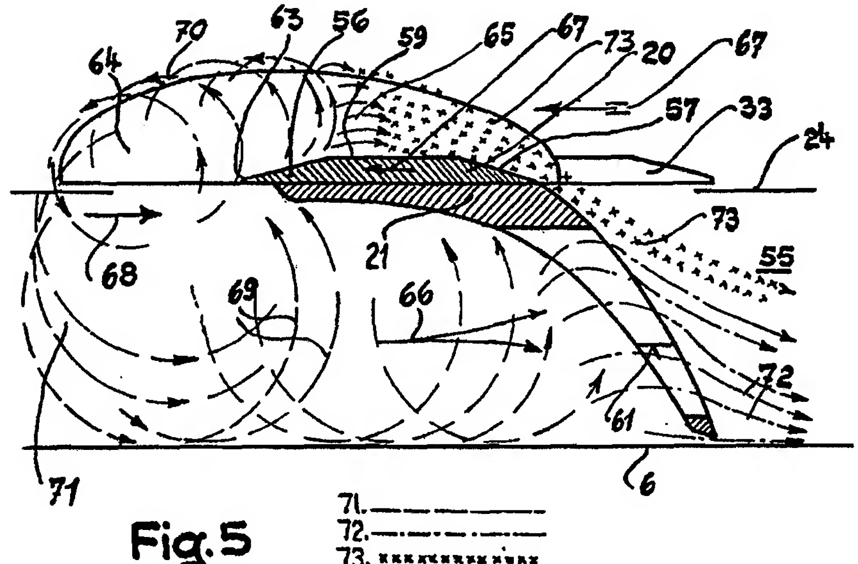
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Fig.5

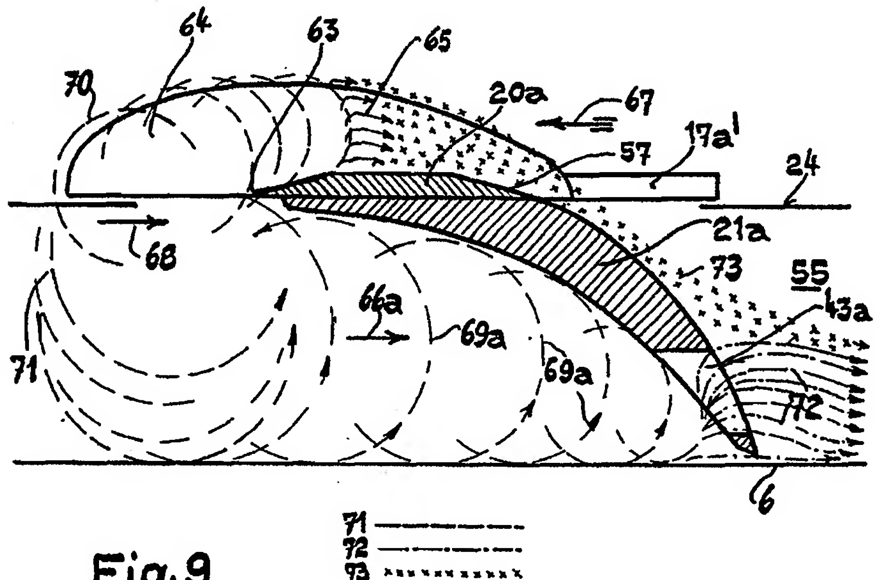
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Fig.9

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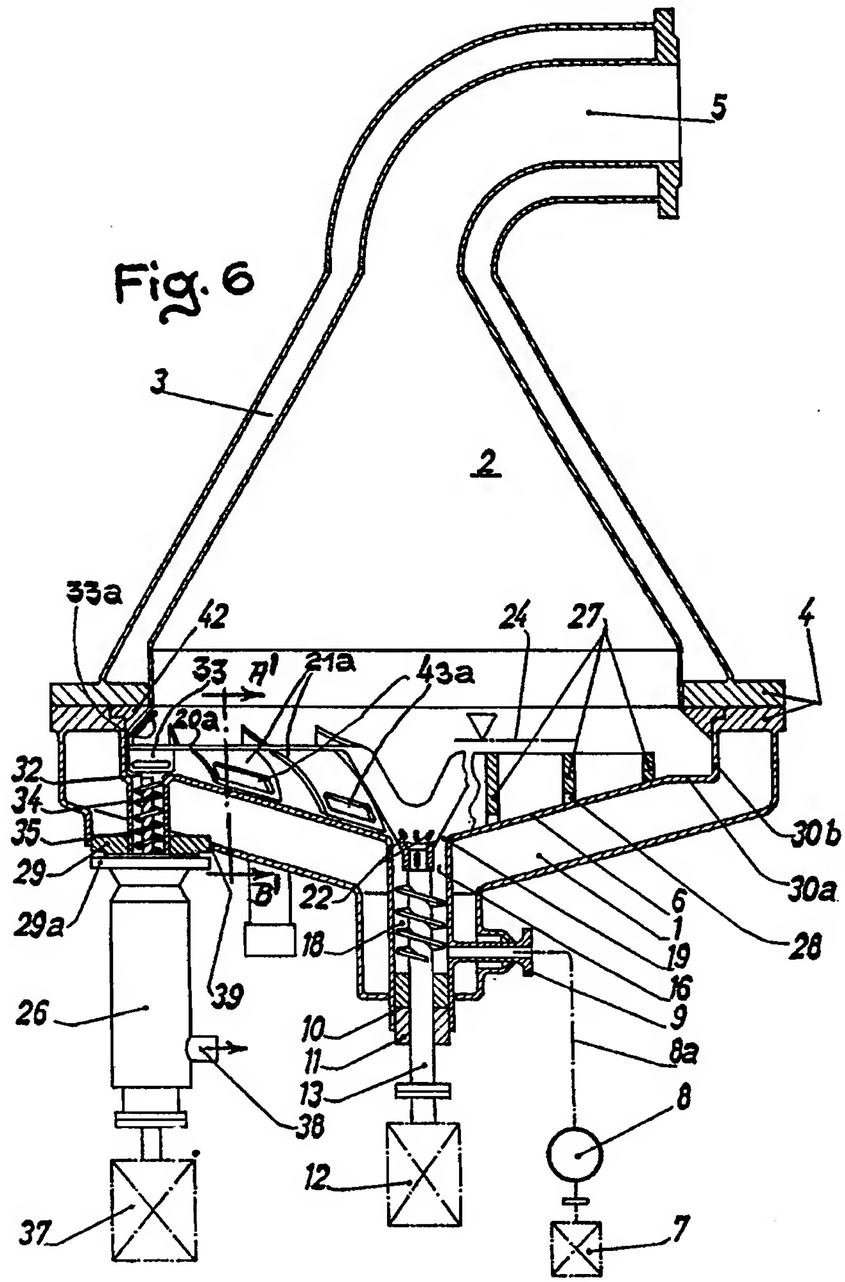
SHEET 5

Fig. 6



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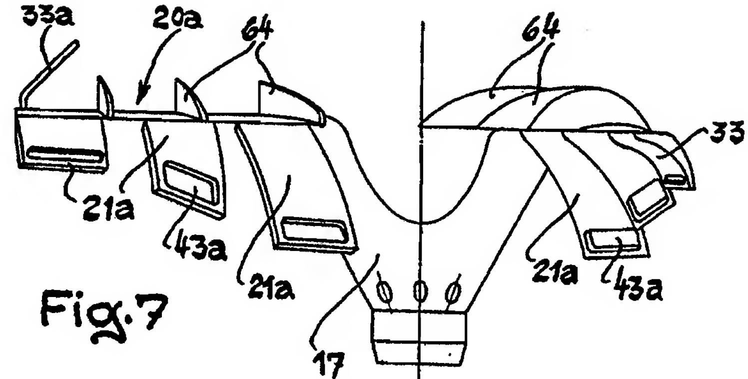

Fig.7

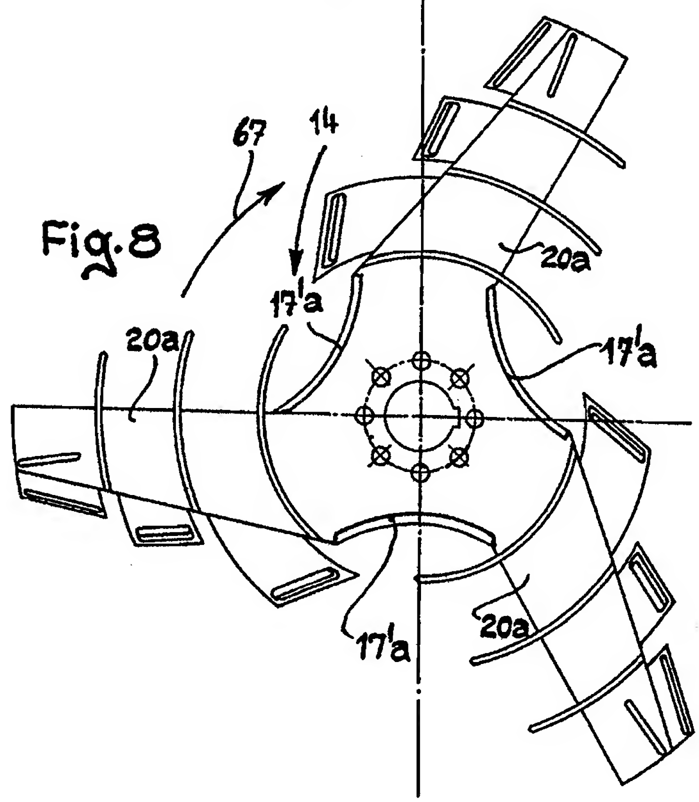

Fig.8